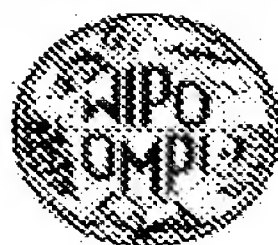


(19) World Intellectual Property Organization
International Bureau



PCT



(43) International Publication Date
13 November 2008 (13.11.2008)

(10) International Publication Number
WO 2008/135775 A1

(51) International Patent Classification:

C12P 19/14 (2006.01) B01F 5/04 (2006.01)
C13K 1/06 (2006.01) C12M 1/00 (2006.01)

(21) International Application Number:

PCT/GB2008/050210

(22) International Filing Date: 21 March 2008 (21.03.2008)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

0708482.5 2 May 2007 (02.05.2007) GB
0710659.4 5 June 2007 (05.06.2007) GB

(71) Applicant (for all designated States except US): **PUR-SUIT DYNAMICS PLC** [GB/GB]; Shackleton House, Kingfisher Way, Hinchingsbrooke Business Park, Huntingdon, Cambridgeshire PE29 6HB (GB).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **THORUP, Jens, Havon** [DK/GB]; 8 Bromley Green Lane, Bury St Edmunds, Suffolk IP32 7GB (GB). **HEATHCOTE, John, Gervase, Mark** [GB/GB]; Pursuit Dynamics plc, Shackleton House, Kingfisher Way, Hinchingsbrooke Business Park, Huntingdon Cambridgeshire PE29 6HB (GB). **FENTON, Marcus, Brian, Mayhall** [GB/GB]; 2 Bushmead

Road, Eaton Socon, St Neots, Cambridgeshire PE19 8BP (GB).

(74) Agent: **MURGITROYD & COMPANY**; Scotland House, 165-169 Scotland Street, Glasgow, Strathclyde G5 8PL (GB).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SI, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: LIQUEFACTION OF STARCH-BASED BIOMASS

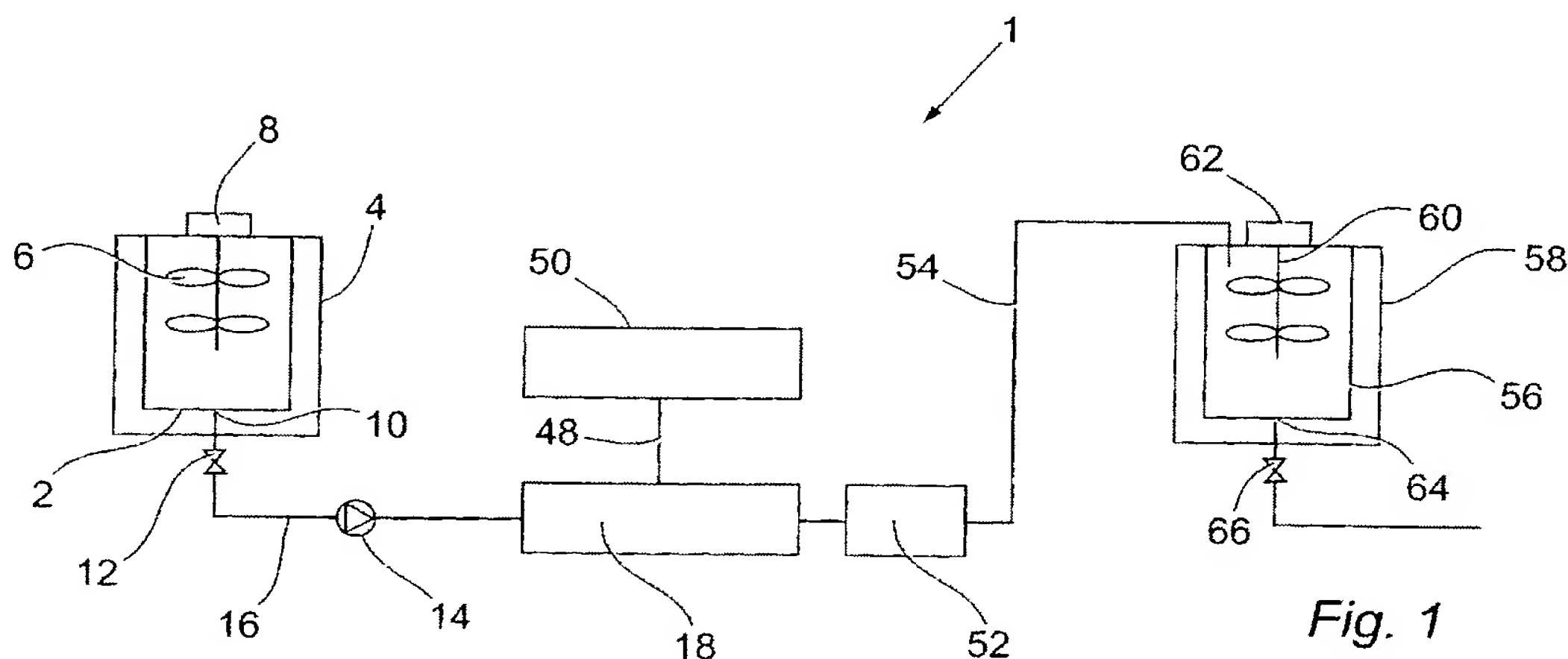


Fig. 1

(57) Abstract: A process for the treatment of a starch-based feedstock is provided. The process comprises mixing together the starch-based feedstock and a working fluid to form a slurry, and hydrating the starch-based feedstock with the working fluid. A liquefaction enzyme is added to the slurry, and the slurry is then pumped into a passage (22) of a starch activation device (100). In the starch activation device (100) a high velocity transport fluid is injected into the slurry through a nozzle (38) communicating with the passage (22), thereby further hydrating the starch-based feedstock and activating the starch content of the slurry. An apparatus (1) is also provided for applying the process to the starch-based feedstock. The process and apparatus presented significantly reduce liquefaction time and the amount of liquefaction enzyme needed, as well as reducing the time of subsequent fermentation processes. Liquefaction yield from the process and apparatus is improved.

WO 2008/135775 A1



Published:

— with international search report

LIQUEFACTION OF STARCH-BASED BIOMASS

The present invention is a biomass treatment process suitable for use in biofuel production. More specifically, the present invention relates to an improved process and apparatus for converting starch-based biomass into sugars for subsequent fermentation.

The process of converting starch-based biomass into sugars is known in biofuel production as liquefaction. This liquefaction process involves extracting starch from starch-based feedstock and then converting the extracted starch into short chain polysaccharides for subsequent saccharification, fermentation and distillation into alcohol such as ethanol, for example.

Liquefaction processes typically involve an initial hydration step of mixing ground starch-based feedstock with water to form a slurry. The water may be pre-heated prior to being mixed with the feedstock. The slurry may additionally be heated in a vessel in order to activate the starch, and is then heated again and mixed with a liquefaction enzyme in order to convert the starch to short chain sugars. The activation stage typically uses steam-jacketed tanks or steam sparge heating to heat the slurry to the desired temperature. At the same time agitation mixers, slurry recirculation loops, or a combination of the two mix the slurry. However, despite the presence of the recirculation pumps these heating methods can result in regions being created in the slurry tank or vessel whose temperature is much greater than the remainder of the tank. In such "slow release" processes, starch hydrated early in the process can be damaged if it comes into contact with these high temperature regions, resulting in a lower yield. These arrangements also do not provide particularly efficient mixing, as evidenced by the heat damage problem discussed above.

These conventional processes normally use separate vessels for the activation and conversion stages of the process. Transfer of the slurry from the activation vessel to the conversion stage vessel is normally accomplished using centrifugal pumps, which impart a high shear force on the slurry and cause further damage to the hydrated starch as a result.

The conversion stage may also use steam- or water-jacketed tanks, or tanks heated by sparge heaters, to raise the temperature of the slurry to the appropriate level for the optimum performance of the enzyme . Alternatively, jet cookers are employed to heat the incoming slurry into the conversion stage vessel.. Not only can the slurry suffer the same heat damage as in the activation stage, but the high temperature regions also contribute to limiting the glucose yield from the process. The excessive heat of these regions promotes Maillard reactions, where the sugar molecules are destroyed due to interaction with proteins also present in the slurry. The combination of these Maillard losses with the shear losses from the transfer pumps limits the glucose yield available. Additionally, existing liquefaction processes require a long residence time for the slurry in the conversion stage to ensure that as much starch is converted to sugars as possible. This leads to a longer production process with increased costs

It is an aim of the present invention to mitigate or obviate one or more of these disadvantages.

According to a first aspect of the present invention, there is provided a process for the treatment of a starch-based feedstock, comprising:
mixing together starch-based feedstock and working fluid to form a slurry;

hydrating the starch-based feedstock with the working fluid;
adding a liquefaction enzyme to the slurry and pumping the slurry
into a passage of a starch activation device; and
further hydrating the starch-based feedstock and activating the
5 starch content of the slurry by injecting a high velocity transport fluid into
the slurry through a nozzle communicating with the passage.

The injection of the transport fluid into the slurry may:

10 apply a shear force to the slurry;
atomise the liquid phase within the slurry to create a dispersed
droplet flow regime;
form a low pressure region downstream of the nozzle; and
generate a condensation shock wave within the passage
downstream of the nozzle by condensation of the transport fluid.

15

The first hydrating step may include heating the slurry within a first vessel
and/or maintaining it at a first predetermined temperature for a first
predetermined period of time.

20 The process may further comprise the step of transferring the slurry to a
second vessel from the starch activation device, and maintaining the
temperature of the slurry in the second vessel for a second predetermined
period of time.

25 The step of transferring the slurry to the second vessel may include
passing the slurry through a temperature conditioning unit to raise the
temperature of the slurry.

The step of heating the slurry in the first and second vessels may also include the step of agitating the slurry for the respective first and second periods of time.

- 5 The activation step may include recirculating the slurry through the starch activation device.

The transport fluid may be steam. The transport fluid may be injected at a supersonic velocity. The working fluid may be water.

10

The step of injecting the transport fluid may comprise injecting the high velocity transport fluid into the slurry through a plurality of nozzles communicating with the passage. The step of injecting the transport fluid into the slurry may occur on a single pass of the slurry through the starch
15 activation device.

The pumping of the slurry may be carried out using a low shear pump.

20

According to a second aspect of the present invention there is provided an apparatus for treating a starch-based feedstock, the apparatus comprising:

hydrating means for mixing and hydrating the feedstock with a working fluid to form a slurry; and

a starch activation device in fluid communication with the first hydrating means;

25

wherein the starch activation device comprises:

a passage having an inlet in fluid communication with the first hydrating means and an outlet; and

a transport fluid nozzle communicating with the passage and adapted to inject high velocity transport fluid into the passage.

30

The hydrating means may comprise a first vessel having an outlet in fluid communication with the inlet of the passage. The hydrating means may comprise a heating means for heating the working fluid and/or the slurry.

5 The apparatus may further comprise a second vessel having an inlet in fluid communication with the outlet of the passage. The second vessel may include insulating means for insulating the contents of the second vessel.

10 Alternatively, the apparatus may further comprise a residence tube section having an inlet in fluid communication with the outlet of the passage. The residence tube may include insulating means for insulating the contents of the residence tube as it passes through.

15 The transport fluid nozzle may be annular and circumscribe the passage. The transport fluid nozzle may have an inlet, an outlet and a throat portion intermediate the inlet and the outlet, wherein the throat portion has a cross sectional area which is less than that of the inlet and the outlet. The passage may be of substantially constant diameter.

20

The apparatus may further comprise a transport fluid supply adapted to supply transport fluid to the transport fluid nozzle.

25 The apparatus may comprise a plurality of starch activation devices in series and/or parallel with one another, wherein the transport fluid supply is adapted to supply transport fluid to the transport fluid nozzle of each device. The apparatus may comprise a plurality of transport fluid supply lines connecting the transport fluid supply with each nozzle, wherein each transport fluid supply line includes a transport fluid conditioning means.

The transport fluid conditioning means may be adapted to vary the supply pressure of the transport fluid to each nozzle.

5 Alternatively, the apparatus may comprise a dedicated transport fluid supply for each transport fluid nozzle. Each transport fluid supply may include a transport fluid conditioning means. Each conditioning means may be adapted to vary the supply pressure of the transport fluid to each respective nozzle.

10 The apparatus may further comprise a temperature conditioning unit located between the starch activation device and the second vessel, the temperature conditioning unit adapted to increase the temperature of fluid passing from the device to the second vessel.

15 The apparatus may further comprise a recirculation pipe adapted to allow fluid recirculation between the outlet of the starch activation device and the first vessel.

20 The apparatus may further comprise a low shear pump adapted to pump fluid from the hydrating means to the starch activation device.

The heating means may comprise a heated water jacket surrounding the first vessel. Alternatively, the heating means may be remote from the hydrating means.

25

The insulating means may comprise a heated water jacket surrounding the second vessel. Alternatively, the insulating means may comprise a layer of insulating material covering the exterior of the second vessel.

The apparatus may further comprise first and second agitation means located in the first and second vessels, respectively. The first vessel may include a recirculation means for recirculating slurry from the outlet to an inlet thereof.

5

A preferred embodiment of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a schematic view of a biofuel processing apparatus;

10

Figure 2 is a longitudinal section view through a starch activation device suitable for use in the apparatus shown in Figure 1; and

Figure 3 shows a graph of the temperature and pressure profile of a slurry as it passes through the device shown in Figure 2.

15

Figure 1 schematically illustrates an apparatus which extracts starch from a starch-based feedstock and then converts the extracted starch into sugars. The apparatus, generally designated 1, comprises a first vessel 2 acting as a first hydrating means. The first vessel 2 has a heating means, which is preferably a heated water jacket 4 which surrounds the vessel 2 and receives heated water from a heated water supply (not shown). The vessel 2 also includes an agitator 6 that is powered by a motor 8. The agitator 6 is suspended from the motor 8 so that it lies inside the vessel 2. At the base of the vessel 2 are an outlet 10 and a valve means 12 which controls fluid flow from the outlet 10. Downstream of the first vessel 2 is a first supply line 16, the upstream end of which fluidly connects to the outlet 10 and valve means 12 whilst the downstream end of the supply line 16 fluidly connects with a reactor 18. A low shear pump 14 may be provided in the supply line 16. The pump 14 may be a centrifugal pump which has been modified in order to reduce shear as fluid is pumped through it.

20

25

30

The reactor 18 is formed from one or more starch activation devices. A suitable fluid mover that may act as a starch activation device is shown in detail in Figure 2. The fluid mover 100 comprises a housing 20 that defines a passage 22. The passage 22 has an inlet 24 and an outlet 26, and is of substantially constant diameter. The inlet 24 is formed at the front end of a protrusion 28 extending into the housing 20 and defining exteriorly thereof a plenum 30. The plenum 30 has a transport fluid inlet 32. The protrusion 28 defines internally thereof part of the passage 22. The distal end 34 of the protrusion 28 remote from the inlet 24 is tapered on its relatively outer surface at 36 and defines a transport fluid nozzle 38 between it and a correspondingly tapered part 40 of the inner wall of the housing 20. The nozzle 38 is in fluid communication with the plenum 30 and is preferably annular such that it circumscribes the passage 22. The nozzle 38 has a nozzle inlet 35, a nozzle outlet 39 and a throat portion 37 intermediate the nozzle inlet 35 and nozzle outlet 39. The nozzle 38 has convergent-divergent internal geometry, wherein the throat portion 37 has a cross sectional area which is less than the cross sectional area of either the nozzle inlet 35 or the nozzle outlet 39. The nozzle outlet 39 opens into a mixing chamber 25 defined within the passage 22.

20

Referring once again to Figure 1, the reactor 18 is connected to a transport fluid supply 50 via a transport fluid supply line 48. The transport fluid inlet 32 of the or each starch activation device 100 making up the reactor is fluidly connected with the transport fluid supply line 48 for the receipt of transport fluid from the transport fluid supply 50.

25

Located downstream of the reactor 18 and fluidly connected thereto is a temperature conditioning unit (TCU) 52. The TCU 52 preferably comprises a fluid mover substantially identical to that illustrated in Figure 2, and will therefore not be described again in detail here. The TCU 52

30

can either be connected to the transport fluid supply 50 or else it may have its own dedicated transport fluid supply (not shown).

5 Downstream of the TCU 52 is a second supply line 54, which fluidly connects the outlet of the TCU 52 with a second vessel 56. The second vessel 56 is similar to the first vessel 2, and therefore has a heated water jacket 58 which surrounds the vessel 56 and receives heated water from a heated water supply (not shown). The vessel 56 also includes an agitator 60 that is powered by a motor 62. The agitator 60 is suspended from the
10 motor 62 so that it lies inside the vessel 56. At the base of the vessel 56 are an outlet 64 and a valve means 66 which controls fluid flow from the outlet 64.

A method of processing starch-based feedstock using the apparatus
15 illustrated in Figures 1 and 2 will now be described in detail. Firstly, a ground starch-based feedstock is introduced into the first vessel 2 at a controlled mass addition flowrate. Examples of suitable feedstock include dry milled maize, wheat or sorghum. Separately, a liquefaction enzyme is mixed with a working fluid, preferably water, and that working fluid is then
20 added to the feedstock in the vessel 2 to form a slurry and to start to hydrate the feedstock. An example of a suitable liquefaction enzyme is Liquozyme SC DS® manufactured by Novozymes of Bagsvaerd, Denmark. The preferred enzyme concentration in the vessel 2 is 0.09-0.18 ml/kg. Preferably, the ratio of feedstock to liquid content in the slurry
25 is 20-40% by weight. Optionally, one or more PH adjusters and/or a surfactant can also be added to the slurry at this point.

Heated water is fed into the water jacket 4 surrounding the vessel 2 and the heated water jacket then heats the slurry to a temperature of typically
30 30-60°C, most preferably 30-40°C, and holds the slurry at this temperature

for 30-120 minutes. The motor 8 drives the agitator 6, which stirs the slurry in the vessel 2 with gentle (i.e. low shear) agitation whilst the slurry is held in the vessel 2.

5 The slurry is held at the desired temperature in the vessel 2 for a sufficient period of time to allow the starch content to be prepared for full hydration. When the slurry has been steeped in the vessel 2 for sufficient time, the valve 12 is opened to allow the slurry to leave the vessel via the outlet 10. The pump 14 pumps the slurry under low shear conditions from the vessel
10 2 through the first supply line 16 to the reactor 18.

Referring again to Figure 2, when the slurry reaches the or each starch activation device 100 forming the reactor 18, slurry will pass into the device 100 through inlet 24 and out of the outlet 26. Transport fluid, which
15 in this non-limiting example is preferably steam, is fed from the transport fluid supply 50 at a preferred pressure of between 5-7 Bar to the, or each, transport fluid inlet 32 via transport fluid supply line 48. Introduction of the transport fluid through the inlet 32 and plenum 30 causes a jet of steam to issue forth through the nozzle 38 at a very high, preferably supersonic,
20 velocity. As the steam is injected into the slurry, a momentum and mass transfer occurs between the two which preferably results in the atomisation of the working fluid component of the slurry to form a dispersed droplet flow regime. This transfer is enhanced through turbulence. The steam preferably applies a shearing force to the slurry
25 which not only atomises the working fluid component but also disrupts the cellular structure of the feedstock suspended in the slurry, such that the starch granules present are separated from the feedstock.

The effects of the process on the temperature and pressure of the slurry
30 can be seen in the graph of Figure 3, which shows the profile of the

temperature and pressure as the slurry passes through various points in the fluid mover 100 of Figure 2. The graph has been divided into four sections A-D, which correspond to various sections of the fluid mover 100. Section A corresponds to the section of the passage 22 between the inlet 24 and the nozzle 38. Section B corresponds to the upstream section of the mixing chamber 25 extending between the nozzle 38 and an intermediate portion of the chamber 25. Section C corresponds to a downstream section of the mixing chamber 25 extending between the aforementioned intermediate portion of the chamber 25 and the outlet 26, while section D illustrates the temperature and pressure of the slurry as it passes through the outlet 26.

The steam is injected into the slurry at the beginning of section B of the Figure 3 graph. The speed of the steam, which is preferably injected at a supersonic velocity, and its expansion upon exiting the nozzle 38 may cause an immediate pressure reduction. At a point determined by the steam and geometric conditions, and the rate of heat and mass transfer, the steam may begin to condense, further reducing the pressure and causing an increase in temperature. The steam condensation may continue and form a condensation shock wave in the downstream section of the mixing chamber 25. The forming of a condensation shock wave causes a rapid increase in pressure, as can be seen in section C of Figure 3. Section C also shows that the temperature of the slurry also continues to rise through the condensation of the steam.

As explained above, as the steam is injected into the slurry through nozzle 38 a pressure reduction may occur in the upstream section of the mixing chamber 25. This reduction in pressure forms an at least partial vacuum in this upstream section of the chamber 25 adjacent the nozzle outlet 39.

Tests have revealed that an approximately 90% vacuum can be achieved in the chamber 25 as the steam is injected and subsequently condenses.

As previously stated, the shear force applied to the slurry and the subsequent turbulent flow created by the injected steam disrupts the cellular structure of the feedstock suspended in the slurry, releasing the starch granules from the feedstock. As the slurry passes through the partial vacuum and condensation shock wave formed in the chamber 25, it is further disrupted by the changes in pressure occurring, as illustrated by the pressure profile in sections B and C of Figure 3.

As the starch granules are separated from the feedstock in the reactor 18, the granules are almost instantaneously further hydrated, heated and activated due to the introduction of the steam. The device(s) 100 making up the reactor 18 simultaneously pump and heat the slurry and complete the hydration and activate or gelatinise the starch content as the slurry passes through. In addition, the reactor 18 mixes the enzymes with the slurry, providing a homogenous distribution and high level of contact with the starch which is now in a liquid phase. The temperature of the slurry as it leaves the reactor 18 is preferably between 74-76°C. Where the reactor 18 comprises a number of starch activation devices in series, the pressure of the steam supplied to each fluid mover can be individually controlled by a transport fluid conditioning means (not shown) so that the optimum temperature of the slurry is only reached as it exits the last fluid mover in the series. The transport fluid conditioning means may be attached directly to the transport fluid supply 50, or else may be located in the transport fluid supply lines 48.

The temperature at which the slurry leaves the reactor 18 is selected to avoid any heat damage to the slurry contents during the activation stage.

However, this temperature may be below the temperature for optimal performance of the liquefaction enzyme, and so the temperature of the slurry may need to be raised without subjecting the slurry to excessively high temperatures or additional shear forces. This gentle heating is
5 achieved using the optional TCU 52 downstream of the reactor 18.

As described above, the TCU 52 comprises one or more fluid movers of the type illustrated in Figure 2. Where there is more than one fluid mover in the TCU 52, they are preferably arranged in series. The pressure of the
10 steam supplied to the fluid mover(s) of the TCU 52 is controlled so that it is comparatively low when compared to that of the steam supplied to the device(s) 100 of the reactor 18. A preferred steam input pressure for the fluid mover(s) of the TCU is between 0.5-2.0 Bar. Consequently, the transport fluid velocity is much lower so no shear force or condensation
15 shock is applied to the slurry by the injected steam as the slurry passes through the TCU 52. Instead, the TCU 52 merely uses the low pressure steam to gently raise the temperature of the slurry.

Once it has passed through the TCU 52, the slurry is preferably at a
20 temperature of between 83-85°C. The slurry then flows downstream through the second supply line 54 into the second vessel 56. The water jacket 58 of the second vessel receives heated water which maintains the slurry at the aforementioned temperature. The slurry is held in the second vessel 56 for a sufficient residence time to allow the enzyme to convert or
25 hydrolyse the starch content into shorter dextrans. During that residence time, the motor 62 drives the agitator 60 to gently agitate the slurry. It has been found that approximately 30 minutes is a sufficient residence time in the present process, compared with a typical residence time of 120 minutes in existing liquefaction processes. The progress of the conversion
30 is monitored during the residence time by measuring the dextrose

equivalent (DE) of the slurry. At the end of the residence time, the slurry can be transferred to a fermentation tank (not shown) via the outlet 64 and control valve 66 of the second vessel 56.

- 5 Using a starch activation device of the type described allows the present invention to heat and activate the starch content of the slurry while avoiding the creation of regions of extreme heat, which can damage the starch content. Prevention of these regions also reduces or eliminates Maillard effects caused by the reaction of proteins with the extracted
- 10 starch. These reactions can prevent conversion of the starch to sugar and therefore reduce yields. Furthermore, the gentle agitation mixing and low shear pumping at a lower temperature also ensures that there are no high shear forces which may damage the starch content of the slurry whilst held in a vessel or being transported between vessels. Such damage
- 15 limits the ultimate glucose yield available from the feedstock.

The starch activation device(s) of the reactor also ensure that the slurry components are more thoroughly mixed than is possible using simple agitator paddles and/or recirculation loops alone. The atomisation of the

20 liquid component of the slurry further ensures a more homogenous mixing of the slurry than previously possible. This improved mixing increases the efficiency of the enzyme in converting starch to shorter dextrins, reducing the time to achieve the desired DE values in the slurry when compared with existing processes.

25 Alternatively, if desired, this process will achieve higher DE values than possible with existing processes.

The shear action and condensation/pressure shock applied to the

30 feedstock component of the slurry when in the reactor further improves the

performance of the present invention as this exposes more of the cellular structure of the feedstock. This allows virtually all the starch granules in the feedstock to be separated, thereby providing improved starch activation rates compared to conventional processes as the enzymatic
5 activation is supplemented by the mechanical activation in the reactor. This also allows the process to provide a starch to sugar conversion ratio of substantially 100%. The process of the present invention therefore may only require the slurry to pass once through the reactor before it is ready to pass to the second vessel for the conversion stage. Hence, yields are
10 much improved as there is no time for loss build up during the process.

Exposing more starch also means that less of the enzyme is needed to achieve the desired DE value of 12-18 before the slurry is transferred to the saccharification and fermentation processes. In addition, the
15 condensation/pressure shock kills bacteria at a relatively low temperature, thereby reducing losses in any subsequent fermentation process.

It has also been discovered that the process and apparatus of the present invention may also improve fermentation rates in the subsequent
20 fermentation process. The improved hydration of the present invention also hydrates some proteins in the feedstock. These hydrated proteins act as additional feedstock to the fermenting yeast, thereby improving the fermenting performance of the yeast.

25 In summary, the process and apparatus of the present invention have been found to provide a number of advantages over existing arrangements. These advantages include an increase of up to 14% in starch to sugar yields, a reduction of up to 50% of the amount of liquefaction enzyme required, a reduction of up to 75% in the residence
30 time for the conversion to take place, and a reduction of up to 30% in the

time taken for the subsequent fermentation of the converted sugars into alcohol.

As described above, the reactor may comprise a plurality of starch
5 activation devices arranged in series and/or parallel. Where the reactor
comprises groups of four or more devices in series, the slurry need not be
maintained in the desired 30-60°C temperature range whilst being
developed in the first vessel. Instead, as each of the devices in the
10 reactor injects high pressure transport fluid into the slurry, the temperature
of the slurry as it leaves the first vessel need only be 20-30°C in this
instance. An antibiotic additive may be added at the same time as the first
enzyme, if desired. Reducing the temperature of the slurry to 20-30°C
reduces the requirement for antibiotic infection control.

15 Whilst the present invention need only utilise one starch activation device
in the reactor, if the required process flow rate demands it the reactor may
comprise a combination of fluid movers in series and/or parallel. This may
also be the case with the temperature conditioning unit made up of one or
more of such fluid movers.

20 The apparatus may also include one or more recirculation pipes which can
selectively recirculate slurry from downstream of the starch activation
device to upstream of the device, so that the slurry can pass through the
device more than once if necessary. Where included, the first vessel may
25 also include such an arrangement so that slurry can pass through the first
vessel more than once if necessary.

Instead of having water jackets, the first and/or second vessel may
alternatively comprise an insulation layer on the exterior surface thereof.
30 The insulation layer keeps the temperature of the slurry inside the vessel

in the desired ranges stated above. The working fluid may be pre-heated by an external heating means (not shown) prior to being mixed with the feedstock. The temperature of the slurry is maintained at the desired temperature in vessel 2 by either using the heated water jacket 4 or the insulation layer.

The low shear centrifugal pump which moves the slurry from the first vessel into the reactor may be replaced with any other suitable low shear pump, such as either a membrane pump or a peristaltic pump, for example.

Whilst the temperature conditioning unit (TCU) described above comprises one or more fluid movers of the type shown in Figure 2, they may be replaced by a heat exchanger. The heat exchanger may be a shell and tube heat exchanger with the slurry passing through a tube and heated water passing through the shell surrounding the tube.

The preferred concentration of the liquefaction enzyme in the slurry during development in the first vessel assumes an average of 15% feedstock moisture content and an average starch content of 75% dry weight.

Whilst the enzyme is preferably introduced to the slurry upstream of the starch activation device, the enzyme may also be introduced in the device or else downstream of the device following activation of the starch content.

Whilst the illustrated embodiment of the invention includes both first and second vessels for handling the slurry, it should be appreciated that the invention need not include the vessels to provide the advantages highlighted above. Instead of a first vessel, the first hydrating means may be a pipe or an in-line mixing device into which the feedstock, working fluid

and enzyme are introduced upstream of the starch activation device. Similarly, the second vessel could be replaced by pipework in which the conversion of the activated starch to sugar takes place.

- 5 Further improvements and modifications may be incorporated without departing from the scope of the present invention.

CLAIMS:

1. A process for the treatment of a starch-based feedstock, comprising:
 - 5 mixing together starch-based feedstock and working fluid to form a slurry;
 - hydrating the starch-based feedstock with the working fluid;
 - adding a liquefaction enzyme to the slurry;
 - pumping the slurry into a passage of a starch activation device; and
 - 10 injecting a high velocity transport fluid into the slurry through a nozzle communicating with the passage, thereby further hydrating the starch-based feedstock and activating the starch content of the slurry.
2. The process of Claim 1, wherein the step of injecting the transport
15 fluid into the slurry comprises:
 - applying a shear force to the slurry;
 - atomising the liquid phase within the slurry to create a dispersed droplet flow regime;
 - forming a low pressure region downstream of the nozzle; and
 - 20 generating a condensation shock wave within the passage downstream of the nozzle by condensation of the transport fluid.
3. The process of either preceding claim, wherein the hydrating step includes heating the slurry and/or maintaining it at a first predetermined
25 temperature within a first vessel for a first predetermined period of time.
4. The process of Claim 3 further comprising the step of transferring the slurry to a second vessel from the starch activation device, and maintaining the temperature of the slurry in the second vessel for a
30 second predetermined period of time.

5. The process of Claim 4, wherein the step of transferring the slurry to the second vessel includes passing the slurry through a temperature conditioning unit to raise the temperature of the slurry.

5

6. The process of Claim 4 or Claim 5 further comprising the step of agitating the slurry in the first and second vessels for the respective first and second periods of time.

10 7. The process of any preceding claim, wherein the transport fluid is steam.

8. The process of any preceding claim, wherein the transport fluid is injected at a supersonic velocity.

15

9. The process of any preceding claim, wherein the working fluid is water.

10. The process of any preceding claim, wherein the step of injecting the transport fluid comprises injecting the high velocity transport fluid into the slurry through a plurality of nozzles communicating with the passage.

20

11. The process of any preceding claim, wherein the step of injecting the transport fluid into the slurry occurs on a single pass of the slurry through the starch activation device.

25

12. The process of any of Claims 1 to 10, wherein the step of injecting the transport fluid includes recirculating the slurry through the starch activation device.

30

13. The process of any preceding claim, wherein the pumping of the slurry is carried out using a low shear pump.

14. An apparatus for treating a starch-based feedstock, the apparatus
5 comprising:

hydrating means for mixing and hydrating the feedstock with a working fluid to form a slurry; and

a starch activation device in fluid communication with the hydrating means;

10 wherein the starch activation device comprises:

a passage having an inlet in fluid communication with the hydrating means and an outlet; and

a transport fluid nozzle communicating with the passage and adapted to inject high velocity transport fluid into the passage.

15

15. The apparatus of Claim 14, wherein the hydrating means comprises a heating means for heating the working fluid and/or the slurry.

16. The apparatus of Claim 15, wherein the hydrating means comprises
20 a first vessel having an outlet in fluid communication with the inlet of the passage.

17. The apparatus of Claim 16, wherein the heating means comprises a heated water jacket surrounding the first vessel.

25

18. The apparatus of either Claim 15 or Claim 16, wherein the heating means is remote from the hydrating means.

19. The apparatus of Claim 16 further comprising a second vessel
30 having an inlet in fluid communication with the outlet of the passage.

20. The apparatus of Claim 19, wherein the second vessel includes insulating means for insulating the contents of the second vessel.
- 5 21. The apparatus of any of Claims 14 to 18 further comprising a residence tube section having an inlet in fluid communication with the outlet of the passage.
- 10 22. The apparatus of Claim 21, wherein the residence tube includes insulating means for insulating the contents of the residence tube as it passes through.
- 15 23. The apparatus of any of Claims 14 to 22, wherein the transport fluid nozzle is annular and circumscribes the passage.
- 20 24. The apparatus of any of Claims 14 to 23, wherein the transport fluid nozzle has an inlet, an outlet and a throat portion intermediate the inlet and the outlet, wherein the throat portion has a cross sectional area which is less than that of the inlet and the outlet.
- 25 25. The apparatus of any of Claims 14 to 24, wherein the passage is of substantially constant diameter.
26. The apparatus of any of Claims 14 to 25 further comprising a transport fluid supply adapted to supply transport fluid to the transport fluid nozzle.
27. The apparatus of Claim 26 comprising a plurality of starch activation devices in series and/or parallel with one another, wherein the transport

fluid supply is adapted to supply transport fluid to the transport fluid nozzle of each device.

5 28. The apparatus of Claim 27 comprising a plurality of transport fluid supply lines connecting the transport fluid supply with each nozzle, wherein each transport fluid supply line includes a transport fluid conditioning means.

10 29. The apparatus of Claim 28, wherein the transport fluid conditioning means is adapted to vary the supply pressure of the transport fluid to its respective nozzle.

15 30. The apparatus of Claim 26 comprising a dedicated transport fluid supply for each transport fluid nozzle.

31. The apparatus of Claim 30, wherein each transport fluid supply includes a transport fluid conditioning means.

20 32. The apparatus of Claim 31, wherein each conditioning means is adapted to vary the supply pressure of the transport fluid to each respective nozzle.

25 33. The apparatus of any of Claims 14 to 32 further comprising a temperature conditioning unit located downstream of the starch activation device, the temperature conditioning unit adapted to increase the temperature of fluid leaving the passage of the device.

30 34. The apparatus of any of Claims 14 to 33 further comprising a recirculation pipe adapted to allow fluid recirculation from downstream of the starch activation device to upstream of the starch activation device.

35. The apparatus of any of Claims 14 to 34 further comprising a low shear pump adapted to pump fluid from the hydrating means to the starch activation device.

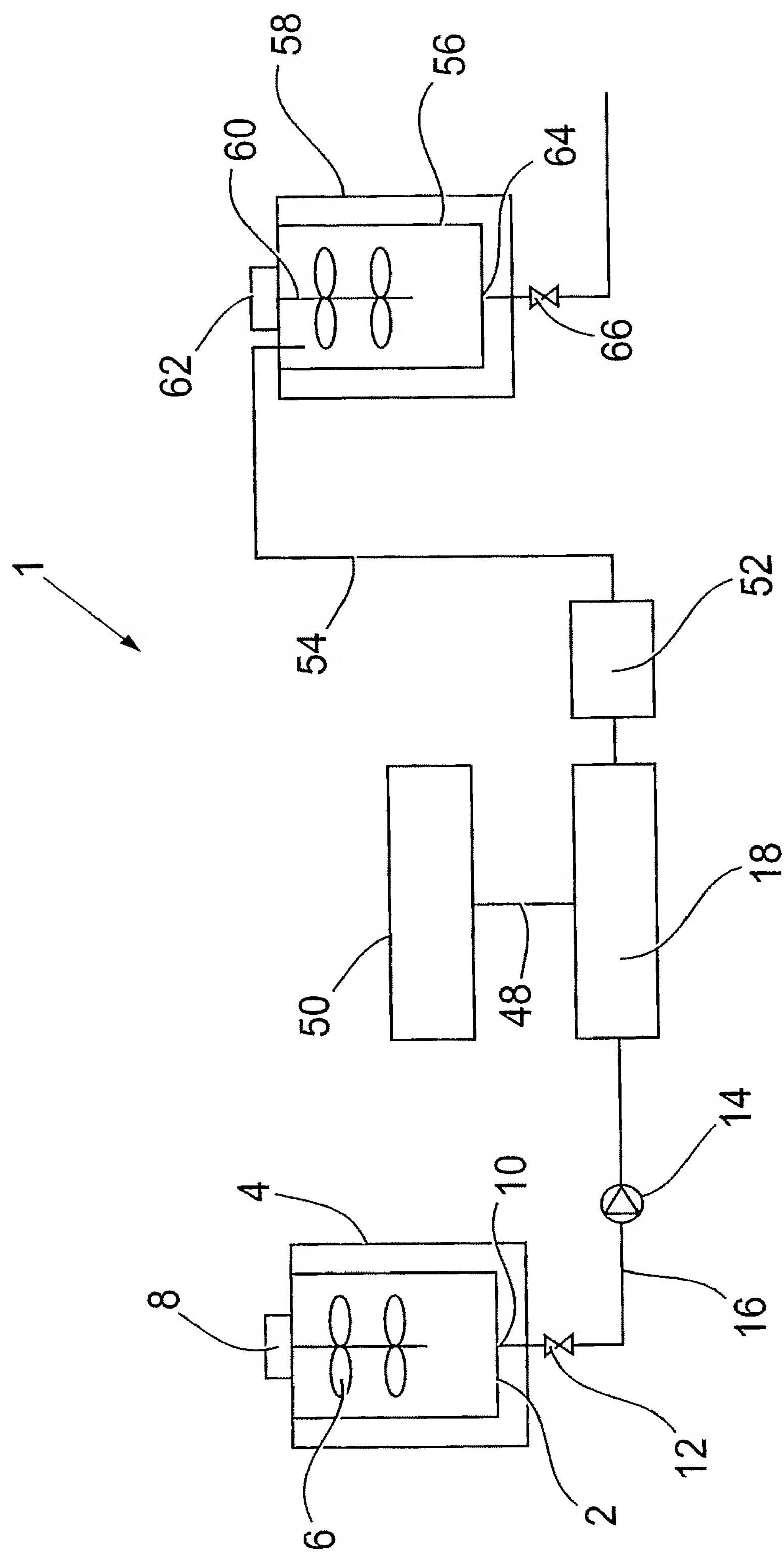


Fig. 1

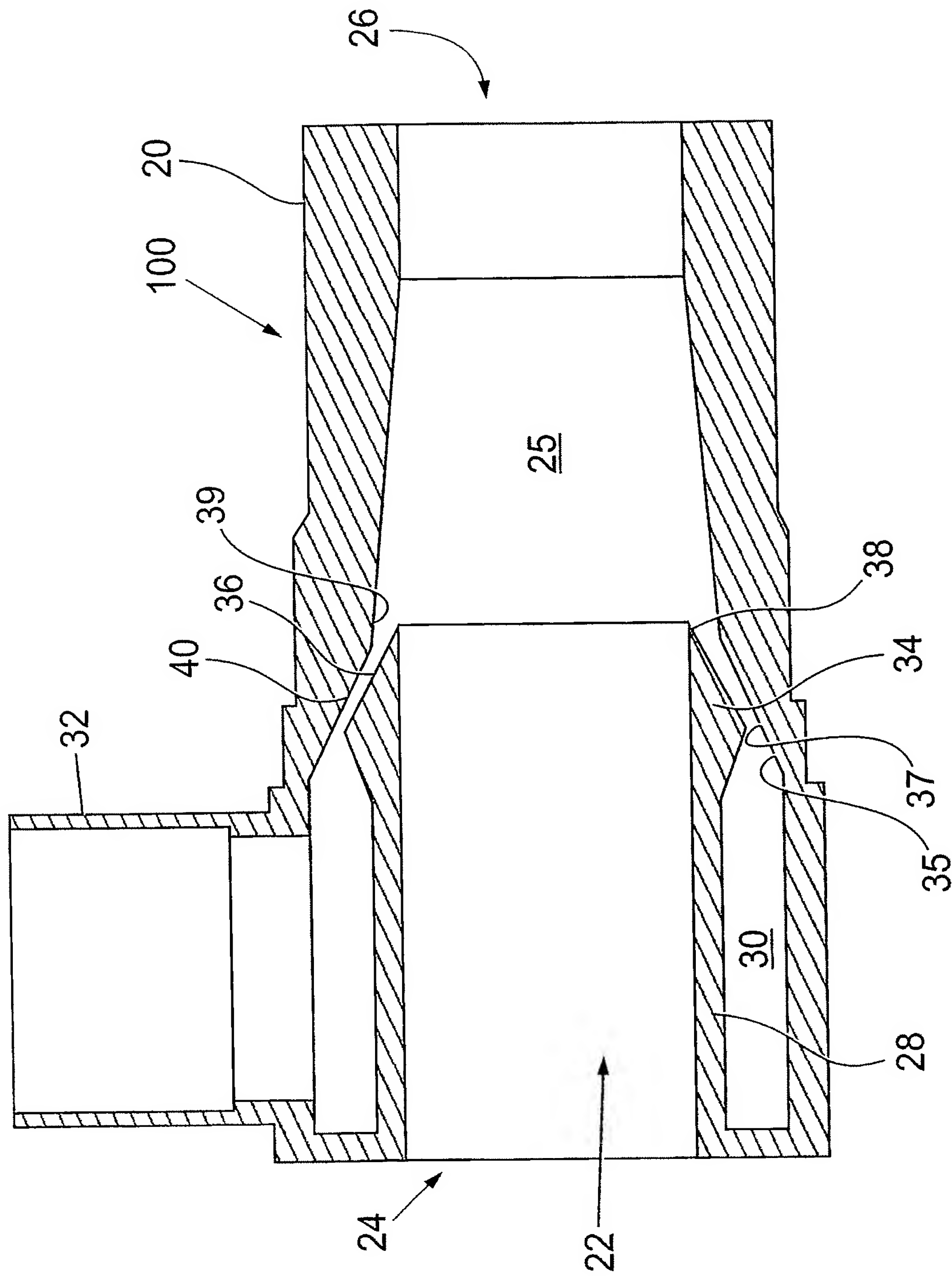


Fig. 2

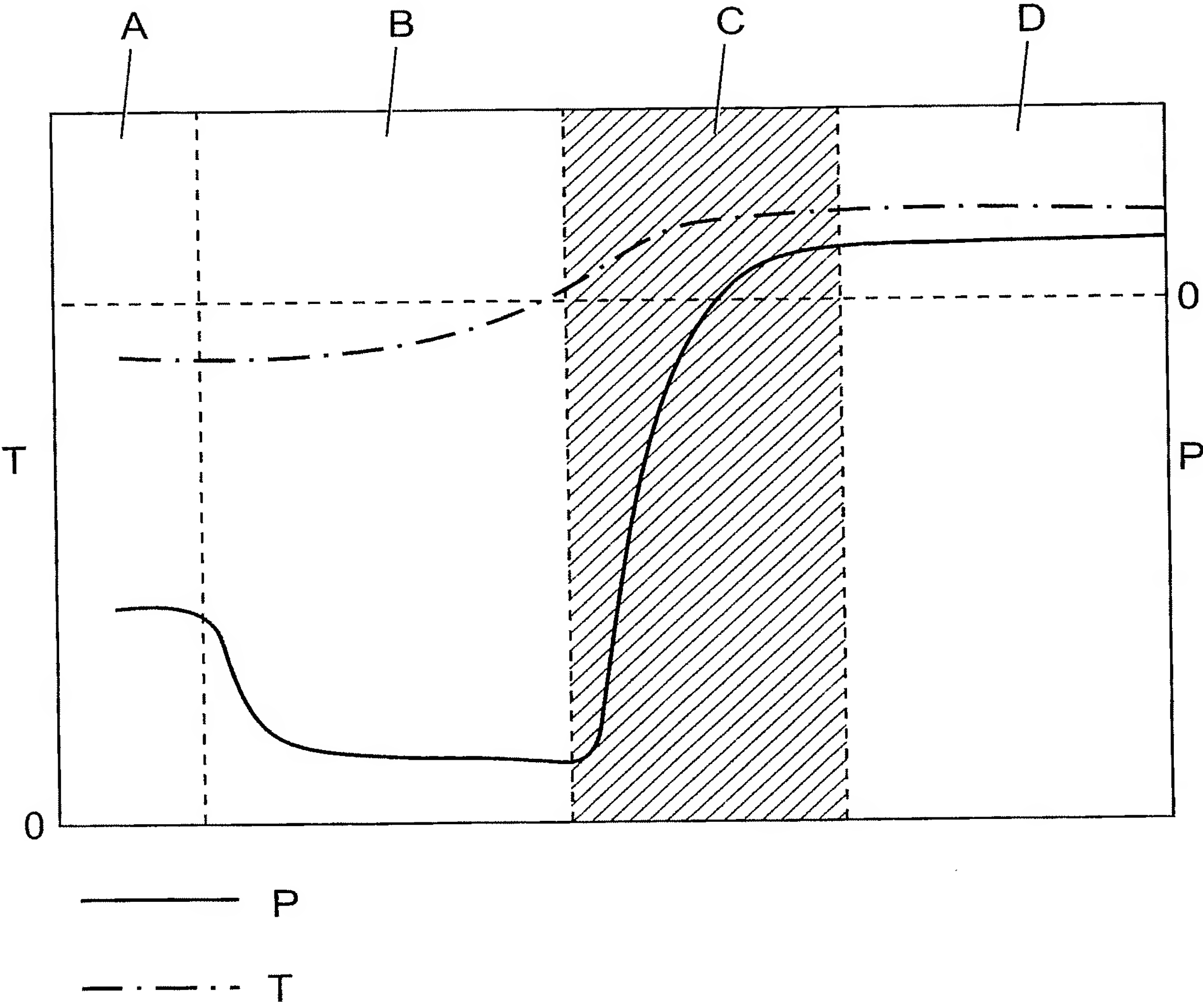


Fig. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2008/050210

A. CLASSIFICATION OF SUBJECT MATTER INV. C12P19/14 C13K1/06 B01F5/04 C12M1/00				
According to International Patent Classification (IPC) or to both national classification and IPC				
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) C12P C13K C12M B01F				
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched				
Electronic data base consulted during the international search (name of data base and, where practical, search terms used) EPO-Internal, WPI Data, EMBASE, BIOSIS				
C. DOCUMENTS CONSIDERED TO BE RELEVANT				
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.		
X	GB 1 028 211 A (ESCHER WYSS GMBH) 4 May 1966 (1966-05-04) page 1, lines 8-73 pages 3-5; examples 1-3 figures 1-4 -& GB 995 660 A (ESCHER WYSS GMBH) 23 June 1965 (1965-06-23) page 2, line 9 - page 4, line 94 figures 1-8 -----	1, 2, 4, 5, 7, 9-12, 14-16, 19, 21, 23, 25, 26, 30-32, 34		
<input type="checkbox"/> Further documents are listed in the continuation of Box C.				
<input checked="" type="checkbox"/> See patent family annex.				
* Special categories of cited documents : <table border="0"> <tr> <td> *A* document defining the general state of the art which is not considered to be of particular relevance *E* earlier document but published on or after the international filing date *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) *O* document referring to an oral disclosure, use, exhibition or other means *P* document published prior to the international filing date but later than the priority date claimed </td> <td> *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. *&* document member of the same patent family </td> </tr> </table>			*A* document defining the general state of the art which is not considered to be of particular relevance *E* earlier document but published on or after the international filing date *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) *O* document referring to an oral disclosure, use, exhibition or other means *P* document published prior to the international filing date but later than the priority date claimed	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. *&* document member of the same patent family
A document defining the general state of the art which is not considered to be of particular relevance *E* earlier document but published on or after the international filing date *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) *O* document referring to an oral disclosure, use, exhibition or other means *P* document published prior to the international filing date but later than the priority date claimed	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. *&* document member of the same patent family			
Date of the actual completion of the international search 24 July 2008		Date of mailing of the international search report 04/08/2008		
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016		Authorized officer Schröder, Gunnar		

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2008/050210

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
GB 1028211	A	04-05-1966	CH 399372 A	15-09-1965
			CH 440176 A	15-07-1967
			DE 1567367 A1	02-07-1970
			DE 1172620 B	18-06-1964
			DE 1190890 B	08-04-1965
			DE 1189030 B	11-03-1965
			GB 995660 A	23-06-1965
			NL 283530 A	
			NL 7313559 A	25-01-1974
			US 3219483 A	23-11-1965
			US 3308037 A	07-03-1967
GB 995660	A	23-06-1965	CH 399372 A	15-09-1965
			CH 440176 A	15-07-1967
			DE 1567367 A1	02-07-1970
			DE 1172620 B	18-06-1964
			DE 1190890 B	08-04-1965
			DE 1189030 B	11-03-1965
			GB 1028211 A	04-05-1966
			NL 283530 A	
			NL 7313559 A	25-01-1974
			US 3219483 A	23-11-1965
			US 3308037 A	07-03-1967

